ON THE EFFECTS OF ELECTRICITY AND MAGNETISM ON DEVELOPMENT.

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IN a former paper in this *Journal*[1] I detailed briefly the results which I had obtained from passing a small constant current through hens' eggs during the process of incubation. I propose to describe in this communication some further experiments of a similar nature conducted with hens' eggs, and with trout and silkworm ova.

I. INFLUENCE OF MAGNETISM ON THE DEVELOPMENT OF HENS' EGGS.

In the first series of experiments in this direction I placed the eggs, twelve in number, between two small bar magnets (1·9 × 0·6 cm. at poles). Temperature and other conditions in this, as in all the other experiments, save where the contrary is indicated, were normal. Of these twelve eggs, four were placed between the magnets, a second group of the same number alongside of one of them, and a third on the other side of the second group, thus at some little distance from the magnet itself. When examined on the fourteenth day, of the first four all had developed normally with this exception, that one of them had an extra toe on each foot,—too common an abnormality, however, to be set down to the score of the magnet. Of the second four, three had developed normally, and in the remaining egg there was only a small dead embryo. In the third four, the group furthest from the magnets, one was normally developed, one had not developed at all; the remaining two shells contained small dead embryos.

The magnets used in this experiment being of small power, I thought it better to substitute on future occasions a more powerful instrument, and in the remaining experiments I used a horseshoe magnet of the largest size capable of being placed in my incubator. The poles of this instrument, 4·7 × 1·3 cm. in

[1] "On certain early Malformations of the Embryo," vol. xxvii. p. 436.

size and 1·0 cm. apart, were capable of sustaining a weight of eight pounds. The eggs were grouped as closely around the poles of the magnet as possible, six being introduced at a time on five occasions, and twelve on two. Of the fifty-four eggs thus experimented upon, twelve showed no sign of development whatsoever, being probably unfertilised, and nineteen were, at the time of their examination, of normal size and appearance for their age. The remaining twenty-three presented obvious abnormalities, of which with one exception all belonged to the class of early malformations associated with deficient development of the area vasculosa. In some of these cases the sinus terminalis was represented by a wide ring of closely opposed dots, in the centre of which were to be seen scanty collections of blood-islands and streaky vessels, a few of which at times appeared to connect with the interior of the embryo, though more often there was no obvious connection between the latter and the external vascular system.

In other cases the sinus terminalis was only represented by a crescent-like arrangement of apparently uncommunicating dots, situated at one side or other of the egg, the internal appearances being similar to those just mentioned, but usually confined almost exclusively to the side where the crescent lay. In all these cases the embryo in the centre was small, generally contorted or otherwise deformed, dead, sometimes œdematous, sometimes partially macerated. In the one exception there was also an imperfect area vasculosa formation, that structure being large in circumference, but very irregularly formed internally. The body of the embryo was, however, hyperæmic,—in fact, engorged with blood, especially on its left side, on which it in part lay. The allantois in this case was well developed and vascularised.

It should be mentioned, that in these experiments there was, so far as I could ascertain,—and I directed especial attention to this point,—no relation between the position of the eggs with regard to the poles of the magnet and the fate of the contained embryo. That the number of abnormally developed embryos was unduly large in these experiments is obvious, but I am not prepared to go further than this statement in associating the condition with the magnetic field in which it was produced. I

will therefore content myself with simply recording the results which I have obtained, as a contribution to the now rapidly growing literature of artificial teratogeny. In this connection it may perhaps be well to briefly summarise the results of the only other experiments of the kind with which I am acquainted, diverse as they are from those obtained by me. Maggiorani,[1] during the process of artificial incubation, exposed a number of eggs to the action of powerful magnets. A similar set of eggs were hatched in same manner, but apart from the magnetic influence, as controls. Cases of arrested development were four times more numerous in the first group than in the second. Microscopical examination showed that the arrest was probably due to an intense vascularisation of the yolk-sac. (This observation is curiously opposite to mine.) After the hatching out of the chicks, the mortality in the magnetic group was three times greater than that of the normal. All the control chicks reached their full development, whilst of the 114 of the first group 60 presented notable imperfections. Their movements were also abnormal, and there were three cases of paralysis and two of contractions. Six of the chickens arrived at maturity. Of these, two were cocks of a splendid stature, and endowed with an insatiable reproductive appetite. With the four pullets it was quite the contrary. One of them never laid at all, and the three others generally produced merely minute eggs, without yolks or germinal spots.

II. Influence of Magnetism on the Development of Silkworms.

Some years ago I was much interested in reading the results of some experiments made by Mr Slater[2] in connection with the development of caterpillars under the influence of magnets. He placed three caterpillars of the common large white (cabbage) butterfly in a box between the poles of two bar magnets. Three others of the same brood were placed in a similar box, but apart from the magnetic influence. Both boxes were placed under

[1] *Atti. R. Acc. d. Lincei*, viii. (1884) p. 274 (Abstr. in *Jl. Roy. Microsc. Soc.* iv. 861).

[2] *Trans. Entom. Soc. Lond.*, 1885 (Abstr. in *Jl. Roy. Microsc. Soc.*, v. 988).

exactly identical conditions as regards light, heat, and supply of food. Two of the caterpillars between the magnets shrivelled up and died without passing into the pupa state. Thinking that they might have been attacked by some parasite, the observer removed them into another box and kept them for some time. As no ichneumons or other parasites made their appearance he dissected the bodies carefully under the microscope, and found no traces of parasitic injury. The remaining caterpillar, and all the three which had not been exposed to the magnets, became pupæ in due course and came out in May. The non-magnetised ones were perfectly normal and healthy, and when released after examination flew away, but the survivor of the magnetised set was a cripple. It had merely rudimentary stumps in place of antennæ, the wings on the left side were expanded, and the legs on the same side were smaller than on the right. As it seemed to me that the number of caterpillars used by Mr Slater was far too small for purposes of generalisation, I determined to repeat the experiment with much larger numbers, and I selected silkworms for my purpose because there is no difficulty in procuring them in any quantity, and their method of development is, of course, perfectly familiar to everybody. I placed, therefore, one hundred silkworms, of the smallest size at which they can well be purchased, in a tray, which was suspended immediately above the poles of a large horseshoe magnet. As I was not circumscribed by space as in the previous experiments, I used a much larger instrument, having poles $7{\cdot}2 \times 2{\cdot}5$ cm. and $3{\cdot}0$ cm. apart, and capable of supporting a weight of twenty-two pounds. With the aid of a compass it was easy to show that the entire of the tray was well within the magnetic field. One hundred other silkworms belonging to the same brood were placed in a similar tray and in the same room, but outside the field of the magnet. The occupants of both trays were fed with mulberry leaves, and treated in every way as regards light, air, &c., identically. In the process of time the occupants of both trays became fewer from deaths and accidents, but eventually exactly the same number from each, viz. forty-two, spun. From the cocoons there emerged of the magnetic lot thirty-six, being twenty-one males and fifteen females; of the non-magnetic, thirty-three, being seventeen males and sixteen females. In each batch there was

one abnormal moth, that of the magnetic group being a male, with very small crumpled wings, and that of the non-magnetic, also a male, having the wings of the left side about half the size of those of the right. It is quite obvious that in this experiment the carrying on of the development of the caterpillars in a magnetic field of considerable intensity had no evil effect upon them.

III. Influence of Electricity and Magnetism on the Development of Trout Ova.

With the object of ascertaining what effect, if any, is produced upon fish ova by allowing them to hatch either in a magnetic field or between the poles of a battery, I arranged three tanks, fed by water from the same tap, but not communicating with one another, as each had its own overflow. At the angles of one of these, and in the line of the current of water, were dipped the poles of two sawdust Daniell batteries. Over the second I suspended the horseshoe magnet used in the silkworm experiment, with the poles downwards, and just above the level of the contained water. It was ascertained by the use of a compass that the entire of the tank was well within the field of the magnet. The third tank was used as a control. In each of these tanks about three hundred ova of the trout were placed. They were of different ages, from those only with danger capable of travelling, to eyed specimens. I obtained them from the Trent Fishery Company at Milton, and was able to place them in my tanks a few hours after they had left that place. The results of the experiment carried out under the above-mentioned conditions may be summed up as follows. In the control tank, one hundred and fifty in all hatched out; in the electric, one hundred and seven; and in the magnetic, thirteen. And the deaths were in a similar ratio amongst the fry, for the thirteen lived but a very short time after hatching, and those in the electric tank had all died at a period when there were still a large number (I omitted to take a note of the exact figure) alive in the control. At first sight it would appear as if this experiment proved that the influence of electricity exercised an evil influence upon the development of these ova, and magnetism one of still greater harmfulness, but I am doubtful whether this should be considered as

the true explanation of what occurred. I asked my friend Professor Poynting, for whose kind assistance in these experiments I am very grateful, to look at the experiment when it had been a sufficient time in operation to enable me to form an idea of the direction in which it was tending. He pointed out to me that the running water underneath the poles of the magnet would set up currents of electricity probably much more powerful than the exceedingly small current generated by the Daniell. If this be true, as doubtless it is, it seems probable that the disturbing factor was electricity in both the tanks, and that the more complete failure to develop in that over which the magnet was suspended was due to the stronger current passing through it.

It would be very rash to attempt to express any definite or confident opinions on the results of the above-detailed experiments. It may, however, be said that my experiments tend to prove, especially when taken in conjunction with those of Lombardini,[1] that electricity produces an arresting effect upon development, whilst it seems to me very doubtful whether a magnetic field has any definite effect upon development or not.

[1] "Forme organiche irregolari negli Uccelli e ne' Batrachidi," Pisa, 1868.